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Thermography - A Method for the Evaluation of the Resistance of Military Pilots, Parachutists and Divers at Hypo and Hyperbaric Exposure

Col. Ilie Capanu, maj. Eugen Necula,

*Institutul de Medicina Aeronautica - Aeronautical Medicine Institute (AMI),
70786, str. Mihai Vulcanescu, nr. 88, sect.1, Bucharest, Romania*

Gheorghe Rodan, Patru Spataru,

*Institutul National de Cercetari Aerospatiale - National Institute for Aerospace Research (NIAR),
77538, bd. Iuliu Maniu, nr. 220, sect.6, Bucharest, Romania*

Summary: A mixed team from the AMI and the NIAR has developed a long - term activity in the field of the hypo and hyperbaric exposure of aeronautical staff and divers - relevant to the topics of the HFM Symposium in the field of "Selection and Training". The subject of the work refers to the evaluation of the efficiency of thermography (a non-invasive and not often used investigation method) in the study of the circulatory system answer to the pressure variation during the exposure of the human body to hypo and hyperbaric conditions. Using the thermography, we tried to build-up a monitoring system of the physiological and circulatory system parameters changes at hypo and hyperbaric exposure.

Keywords: thermography, hypo and hyperbaric exposure monitoring system, resistance of military personnel.

Introduction.

Analysing the trend in medical research, it is clear that every year, more and more expensive and sophisticated devices are introduced to achieve the goals of the researchers. Only a few countries or research centres can follow that way, others, not being able to afford themselves such science policy, they have to try to find something different. Our multi-year activity tried to establish how thermography (a non-invasive paraclinic method) is able to contribute in simulated flight or dive conditions to the vascular system parameters monitoring. We showed that thermography, combined with informatics and statistics can offer valuable data to the medicine.

What we obtained is a method - an early warning system - that needs minimum investments and which could cut future costs involving the selection of flight candidates and the eventual loss of flying material by filtering the high risk candidates.

Objective of research

Thermography is a method of research enabling to record the thermal data for different anatomical regions. The temperature is function of different stress applied to the subjects. We tried to analyse the thermal answer of specific professional groups:

- of pilots - to a dynamic stress - hypobaric hypoxia due to the exposure and physical test in a pressure chamber,
- of parachute jumpers simulating the conditions of a real jump in a pressure chamber,
- of divers in hyperbaric conditions due to the exposure in a pressure chamber or real diving in the Black Sea.

The result was the build-up of a system, which could be used to evaluate the risk groups of subjects, offering a method to screen-out the flight candidates.

Design and setting

The scope of the study was to record with thermographic means, the changes in circulatory system during pressure variations due to exposure in a pressure chamber:

- simulating flight conditions at 5500 m altitude and equivalent pressure and oxygen conditions (for pilots and parachute jumpers) and
- conditions for wet or dry depth at 10 m, 20 m or 50 m (for divers).

We used the AMI ÖKG -type pressure chamber with controlled pressure and temperature conditions for the hypobaric conditions and the Medical Naval Centre - Constanta pressure chamber for hyperbaric conditions. The thermal images were recorded with an IRTIS - 200 Russian built system and subsequently analysed with our own dedicated programs.

The results were correlated with the physiological and physiopathological data of subjects.

Protocol and subjects of the study

The study was extended on a three-year period and comprised the analysis of pilots, parachute jumpers and divers. Subsequently we will refer to each group.

1-st group - flying crews. We studied 54 subjects having professions linked to flight (pilots and flight engineers). Statistically they represent a homogenous group having similar background: flight training.

All the subjects were exposed for 15 minutes to hypobaric hypoxia in the pressure chamber. The exposure was between 9.30 and 12.00 AM, two hours after a light breakfast.

| age | pilots | flight engineers |
|--------------|--------|------------------|
| 20-30 | 9 | 6 |
| 30-45 | 29 | 10 |
| Total | 38 | 16 |

We performed the following recordings:

- before exposure - EKG recording
 - blood pressure (BP) and pulse readings
 - thermographical recording.
- during exposure (duration - 15 minutes) - effort test in the 7th minute of the exposure
 - EKG recording - at ground level
 - at 5500 m altitude (before and after the effort test)
- after exposure
 - EKG recording
 - BP and pulse readings,
 - thermographical recording
- 15 minutes after exposure - thermographical recording.

2-nd group - parachute jumpers. We studied 20 parachute jumpers within the same age group and with similar military training. The following recordings were performed

- before exposure - EKG recording
 - blood pressure (BP) and pulse readings
 - thermographical recording.
- after exposure
 - EKG recording
 - BP and pulse readings,
 - thermographical recording
- 15 minutes after exposure - thermographical recording.

3-rd group - divers. The study extended on a group of 16 trained submarine sailors and 9 trainees in a diving school (a homogenous group from the point of view of age and training).

The conditions of thermographical recordings were those required by the European Association of Thermography: approximately 21°C and normal pressure, with restricted air ventilation and controlled humidity. Each of subjects had three series (before, immediately after the exposure and 15 minute after the exposure) of four thermograms (head, arms and hands, feet and legs with frontal and back views). The thermal images of the subjects form an archive, subsequently read and analysed by the dedicated program.

Physiological and physiopathological data

Due to the fact that the recording conditions, physiology, physiopathology and the interpretation of results are different in case of hypobarism and hyperbarism, in the present paper we will refer to the first case - hypobaric hypoxia.

Hypobaric hypoxia - represents the decrease of the atmospheric pressure and implicitly of the partial pressure of oxygen in the breathed air, it appears in the flight at high altitude.

The most important factor in providing the necessary oxygen to the organism is its partial pressure.

| level | atmospheric pressure | O ₂ partial pressure |
|-----------------|----------------------|---------------------------------|
| sea level | 760 mm Hg | 160 mm Hg |
| 5500 m altitude | 405 mm Hg | 85 mm Hg |

At high altitude the human body is subject to the hypoxic stress, its resistance differs from subject to subject. The healthy ones resist to the absence of oxygen at an altitude of 5500m, well trained subjects resist well above - up to 8000 m. The adaptation of the human body is achieved by compensatory physiological mechanisms to provide the necessary oxygen to the principal organs and systems.

These mechanisms are: **a. respiratory**
b. circulatory
c. enzymatic (biochemical)

a.) Respiratory mechanism

The stimulus starting this mechanism is represented by hypoxia. The receptors are:

- specialised nervous cells localised in the lateral reticular formation
- sinocarotidian and cardioaortic chemoreceptors.

The afferent and efferent paths are complex and localized at the level of central and peripheral nervous system. The effectors are the respiratory muscles. The compensatory answer mechanism is represented by the increase in quantity of breathed air

- by increasing the volume of air breathed in a single breathing,
- by increasing the respiratory frequency (hyperventilation).

b.) Circulatory mechanism.

This mechanism is started by the same stimulus - the hypoxia, and is compensating the diminution of the partial pressure of oxygen, by compensating the repartition of blood in different organs, achieving a vasodilatation in the vital ones: brain, heart, kidneys, and a vasoconstriction in rest.

Also it achieves the acceleration of blood flow, by increasing the heart rhythm.

c.) biochemical-enzymatical mechanism

It compensates the low partial pressure of oxygen by:

- increasing the capacity of blood to transport the oxygen from the lungs to the tissues
- adaptation of tissues to less oxygen, using the anaerobe cycle to obtain energy with an oxygen debt, compensated lately, when external conditions return to normal.

The changes in the circulatory system draw changes in local temperatures, visualised, recorded and quantified in the changes of the thermal images.

Results

We divided the two groups: pilots and parachute jumpers in subgroups versus the following three criteria:

A. heredo - colateral antecedents

B. variations of pulse and blood pressure (BP)

C. thermographic abnormalities (not following the theory) due to hypoxic exposure

A. The first classification depends upon the heredo - colateral antecedents of subjects (parents with cardiac diseases: hypertension, vascular cerebral accidents, etc.). We established two groups::

group A.I - subjects with antecedents

group A.II - subjects without antecedents,

considering that the belonging to the group **A.I** represents a risk factor.

B. The second classification of the subjects was versus their clinical parameters (pulse and blood pressure - BP)

group B.I - constant BP and pulse, emphasizing excellent health and an excellent adaptation mechanism,

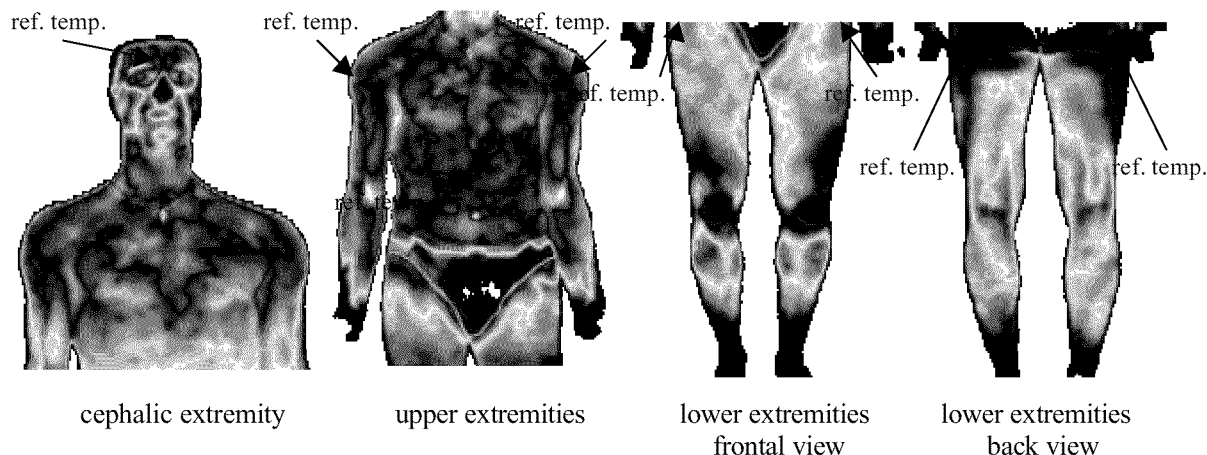
group B.II - moderate increase of values of BP and pulse denoting a good adaptation mechanism.

group B.III - decreased values of BP and pulse meaning a deficit in the adaptative physiological answer.

The belonging to the group **B.III** represents a risk factor

C. The third classification was versus the thermographical results:

We determined the maximum, mean and minimum temperature for each anatomical region and also a reference temperature for each region (a point without blood vessels - forehead, shoulders and hips). (fig.1)



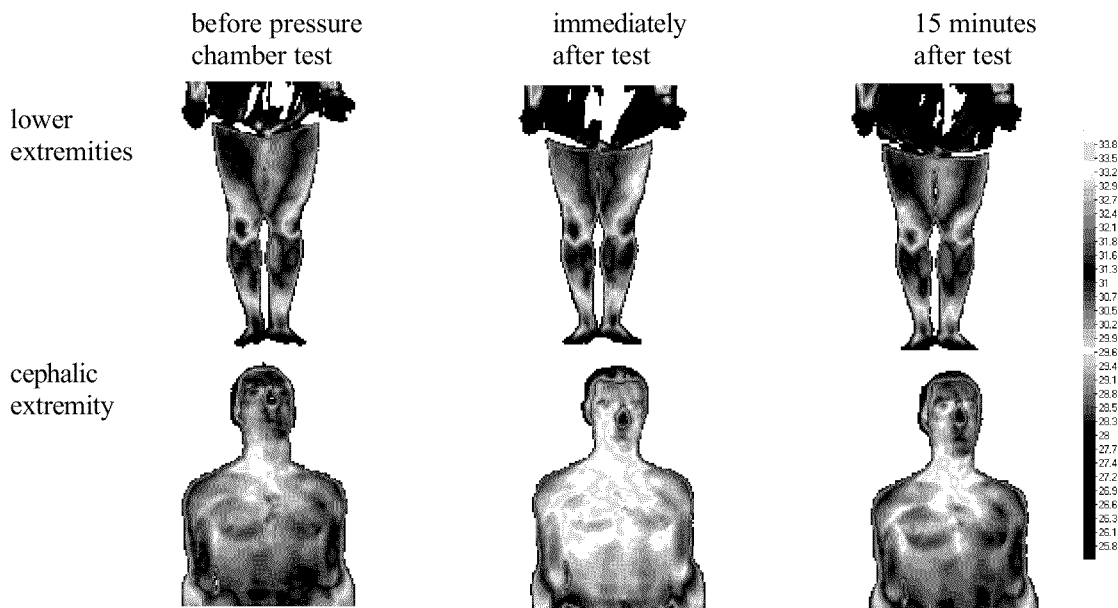
We evaluated the difference between the maximum temperature and the reference temperature (the same for the mean and minimum temperature) for each anatomic region before, immediately after and 15 minutes after the pressure chamber test. Analysing the results we obtained the thermographic classification as follows:

group C.I - normal thermographical recordings.

- decrease of the temperature up to $1,5^{\circ}\text{C}$ of upper and lower extremities after the hypoxic exposure

- increase of the temperature of the cephalic extremity immediately after the test and its return to the initial values after 15 minutes.

This denotes an excellent adaptation to hypoxia.

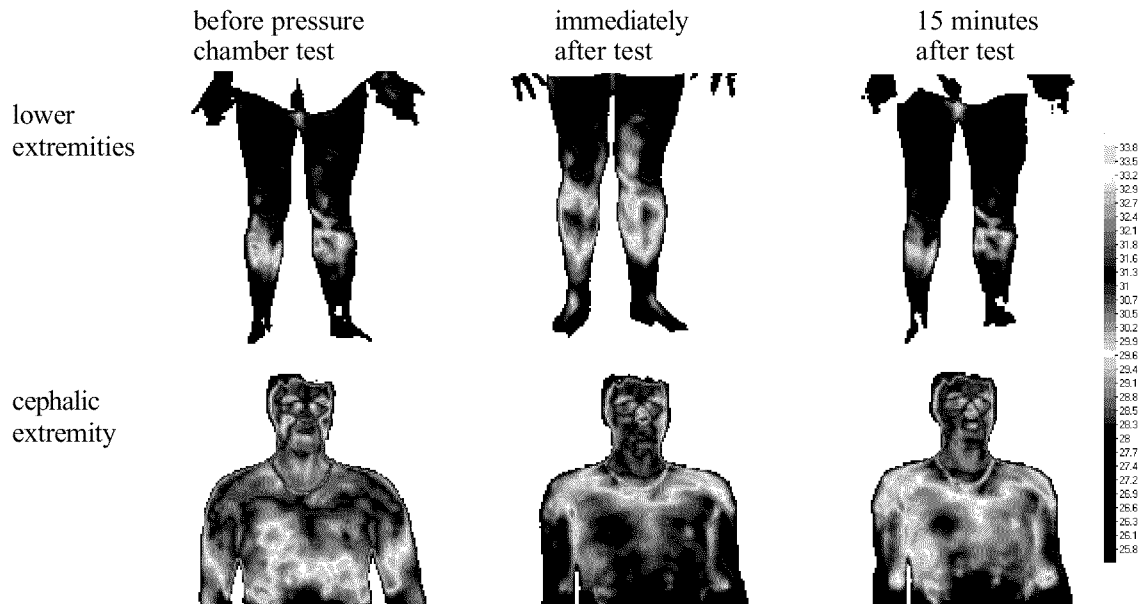


group C.II - inversed thermographical recordings.

- increase of temperature up to 1°C of upper and lower extremities after the hypoxic exposure and its decrease after 15 minutes,

- decrease of the temperature of the cephalic extremity immediately after the test and its increase after 15 minutes.

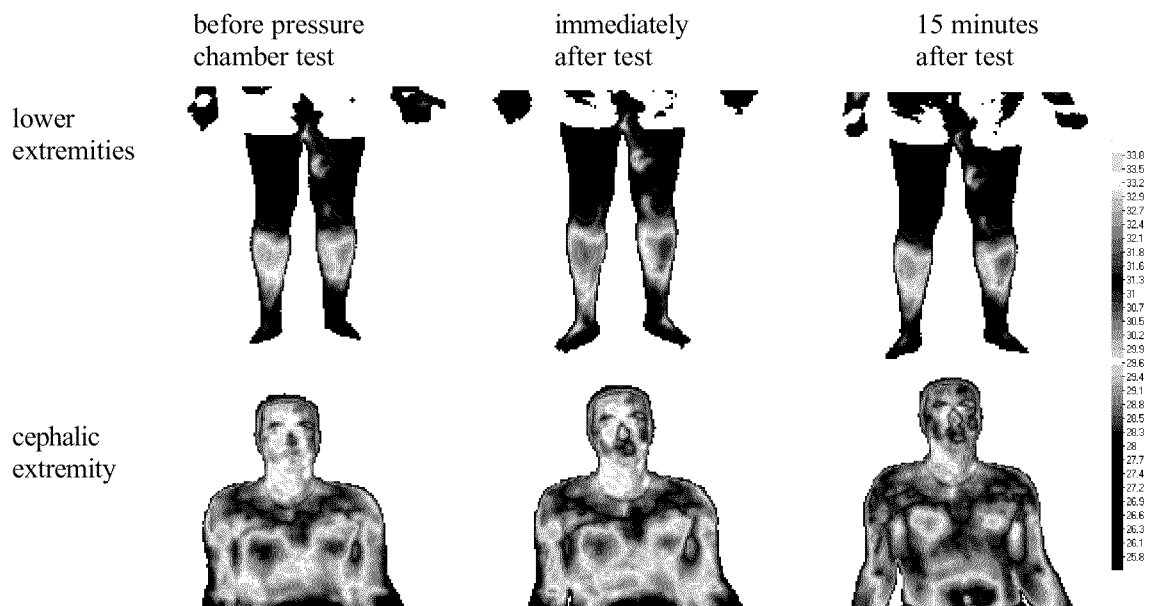
This denotes a good adaptation to hypoxia.



group C.III - thermal inertia

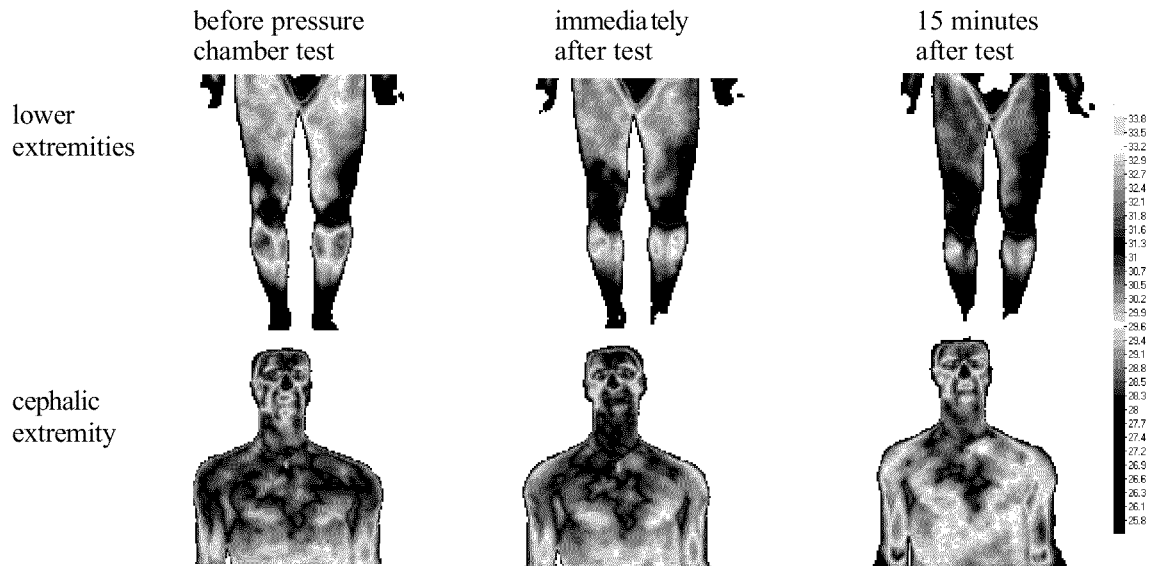
- increase of the temperature of upper and lower extremities after the hypoxic exposure, remaining constant after 15 minutes,
- decrease of the temperature of the cephalic extremity immediately after the test, remaining constant after 15 minutes,

This denotes a less efficient adaptation mechanism.



group C.IV - thermal amputation - there is a thermal amputation in a segment or more, in the extremities.

- denotes circulatory problems evident in hypoxia and latent in normal conditions.



The groups **C.III** and **C.IV** represent risk groups in hypoxia.

To analyse the thermographical images, we used a routine in our dedicated program to evaluate the temperature of the analysed anatomical regions.

- cephalic extremity
- upper lower extremities
- lower extremities - frontal view
- lower extremities - back view

Discussion of results

From the point of view of risk factors we have the following groups:

R.I - the existence of heredo-collateral antecedents (**A.I**)

R.II - AT and pulse decrease at hypoxic stress (physiological group **B.III**),

R.III - thermographical modifications due to hypoxic stress (thermographical group **C.III** and **C.IV**). Concluding these criteria we obtained a new classifications of subjects as follows:

0 degree risk factor group:

- subjects presenting no risk factors, subjects with excellent health and very well trained, with a perfect adaptation mechanism to hypoxic stress..

1-st degree risk factor group

- subjects presenting one risk factor (supposing only a general subsequent medical supervision of the subjects).

2-nd degree risk factor group

- subjects presenting two risk factors (supposing careful subsequent medical supervision)

3-rd degree risk factor group

- subjects presenting three risk factors (supposing careful medical supervision, more frequent testings, shorter professional life).

We are presenting the results referring to the hypoxic-hyperbaric tests (pilots and parachute jumpers)

1-st group - flying crews

We divided the 54 subjects as follows:

| degree of risk factor group | risk factor | number of subjects | % |
|-----------------------------|-----------------------|--------------------|------|
| 0 | no | 7 | 13.0 |
| 1 | R.I | 6 | 11.1 |
| | R.II | 3 | 5.6 |
| | R.III | 10 | 18.5 |
| 2 | R.I+R.II | 2 | 3.7 |
| | R.II+R.II | 9 | 16.7 |
| | R.II+R.III | 5 | 9.3 |
| 3 | R.I+R.II+R.III | 2 | 3.7 |
| | * | 10 | 18.5 |

Note:

* means a group of subjects who were accidentally exposed to psychic stress (conflictual situation) before the pressure chamber test - not included in our statistics.

The concordance between this classification and thennography is 87.5% in the 2-nd risk group and 100% in the 3-rd risk group.

2-nd group - parachute jumpers.

The 20 subjects were grouped as follows

| degree of risk factor group | risk factor | number of subjects | % |
|-----------------------------|---|--------------------|------|
| 0 | no | 3 | 15.0 |
| 1 | R.I | 10 | 50.0 |
| 1 | R.II | 1 | 5.0 |
| 2 | R.I+R.II or R.I+R.III or R.II+R.III | 4 | 20.0 |
| 3 | R.I+R.II+R.III | 2 | 10.0 |

From the point of view of the thermographic classification we had the following classification:

- 9 subjects (45%) with normal answer of both cephalic extremity and upper and lower extremities, denoting excellent adaptation to the hypoxic stress.

- 5 subjects (25%) with normal answer of the cephalic extremity and thermal inertia of upper and lower extremities, denoting relatively good adaptation to the hypoxic stress.

- 4 subjects (20%) with normal answer or thermal inertia of the cephalic extremity and thermal inertia of upper and lower extremities, denoting less efficient adaptation to the hypoxic stress.

- 2 subjects (10%), one with thermal inversion of the cephalic extremity and thermal inertia of upper and lower extremities, the other with thermal inertia of the cephalic extremity and thermal inversion of upper and lower extremities denoting bad adaptation to the hypoxic stress.

The concordance between this classification and thennography is 100% in both 2-nd risk group and 3-rd risk group.

NOTE:

We observed similar concordance in the case of divers in hyperbaric conditions. We hope we will be able to present these results in a future occasion.

Conclusions

- Excellent concordance between clinical risk criteria probes and thermographic abnormalities.
- Thermography reveals circulation system defaults not detected by normal clinical methods.

Thermography can be (must be) used in:

- selection of candidates for professions supposing hypoxic conditions,
- testing and training of flying crews and of parachute jumpers,

The answer to hypoxic stress depends on: - genetical background,
- training in hypoxic conditions.

Medical and thermographic watching reduce the risk factors and warn on the possibility of their accidental apparition.

Perspectives

- Introduction of thermography as usual method to the above mentioned fields.
- The use of the method in cosmic flight conditions